The incremental innovator Vs the trader
Contrasts between the sectoral systems of innovation of the Indian pharmaceutical and telecommunications industries[*]

Sunil Mani[1]

Introduction:

India has pursed a policy of economic growth with technological self-reliance right through the 1950s when she embarked on a planned form of development. Two industries that were targeted especially was the manufacturing of drugs and telecommunications equipments. However the final outcomes have been very different. The drug industry has become self sufficient, has emerged as net exporter and has a strong patenting record abroad while the telecommunications industry has increasingly become dependent on MNCs and imports and the industry does not have many patents to boast of. I argue that although the broad external environments obtaining to both industries are roughly similar, the differences in outcomes could be explained by the differences in their sectoral systems of innovation (SSI). The SSI of the pharmaceutical industry presents an ideal picture where private sector business enterprises occupy the central stage. They have been supported very well by a conducive intellectual property regime, which enabled them to reverse engineer known technologies, and thereby emerge as incremental innovators. On the contrary, a public laboratory dominates the SSI of the telecoms industry and the production enterprises in the system did not have much innovation capability: the enterprises were completely dependent on the public laboratory. The government too did not support the laboratory adequately and very often the public technology procurement- the main instrument pursued by the state supposedly to support domestic technology generation through the laboratory was actually against it. Consequently most of the enterprises constituting the SSI of the telecoms industry have become mere traders- distributing products manufactured elsewhere. The analysis thus brings out important but practical policy prescriptions.

The paper is structured into four sections. Section 1 will outline the framework for analysis, which is essentially the sectoral system of innovation propounded by Malerba (2004).The second section provides some numbers on the innovative performance of the two industries. The third section undertakes a detailed mapping out of the sectoral system of innovation of two high tech in the Indian context, namely the pharmaceutical and telecom equipment industries. India's pharmaceutical industry is one of the most innovative industries in the country's manufacturing sector. The innovation system of the industry has three strong pillars: very pro active government policy regime especially with respect to intellectual property right, strong government research institutes and private sector enterprises which have invested in innovation. The TRIPS compliance of the intellectual property right regime making it mandatory for pharmaceutical products to be patented has not reduced the innovation capability of the industry although it has not

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[*] In working out the ideas contained in this paper I have drawn freely from two of my earlier papers, namely Mani (2005) and Mani (2006).

[1] mani@cds.ac.in

made them work on R&D projects that may lead to the discovery of drugs for neglected diseases of the developing world. Although the innovation system has the capability to develop new chemical entities the two main components of the innovation system, namely the enterprises and the Government Research Institutes does not appear to be having all the requisite capabilities to bring a new drug to the market. Although the state has been very proactive with respect to this industry, this is an area where public policy support is still required**.** On the contrary in the case of the telecom equipment industry, India followed a very rigid policy of indigenous development of domestic technologies by establishing a stand-alone public laboratory that developed state-of-the-art switching technologies. These were then transferred to manufacturing enterprises in both public and private sectors. The enterprises themselves did not have any in-house R&D capability. The public laboratory was also not given any strategic direction, even though it was technologically speaking, very competent. Consequently the country, despite possessing good quality human resource was unable to keep pace with changes in the technology frontier and the equipment industry has now become essentially dominated by affiliates of MNCs. and by imports. The fourth and last section contrasts the two SSIs within the same national system of innovation and draws out the policy implications.

I. The framework of analysis

The paper adopts a Sectoral System of Innovation (SSI) perspective introduced by Malerba (2004). The framework involves mapping out the boundaries of the innovation system in terms of the specific agencies of the government dealing with telecommunications development, the policy framework, the equipment suppliers, the service providers and the regulatory agency and tracking the knowledge flows between these various actors within the system. According to Malerba (2004), every sectoral system of innovation has at least three blocks: (i) knowledge, technological domain, and boundaries; (ii) actors, relationships and networks; and (iii) institutions. These three blocks may be elaborated as follows. First, knowledge plays a central role in innovation. It has to be absorbed by firms through their differential abilities accumulated over time. Knowledge differs across sectors in terms of domains. One knowledge domain refers to the specific scientific and technological fields at the base of innovative activities in a sector. The boundaries of sectoral systems are affected by knowledge base and technologies. Second, sectoral systems are composed of heterogeneous actors. Firms are the key actors in the generation, adoption, and use of new technologies. Actors also include users and suppliers who have different types of relationships with the innovating, producing or selling firms. Other types of agents in a sectoral system are non-firm organizations, government agencies, local authorities, and so on. In various ways, they support innovation, technological diffusion, and production by firms, but again their role greatly differs among sectoral systems. Third, in all sectoral systems, institutions play a major role in affecting the rate of technological change, the organization of innovative activity and performance. Innovation greatly differs across sectors in terms of sources, actors, features, boundaries and organization.

II. The innovative performance of India’s pharmaceutical and telecom industries

The pharmaceutical industry is more successful from the innovation point of view (Table 1). Three indicators are used: (i) trade balance; (ii) R&D expenditure; and (iii) number of US patents granted.

Table 1: Innovative performance of India's Pharmaceutical and Telecommunications Equipment Industries

Pharmaceutical Industry				Telecommunications Equipment Industry			
	Trade balance (Millions of US $)	**R&D expenditure (Millions of US $)**	**Number of US patents granted**	**Trade balance (Millions of US $)**	**R&D expenditure (Millions of US $)**	**Number of US patents granted**	
1990-91	304.1	42.13		-71.77	7.48	1	
1991-92	402.2	39.95		-130.38	7.41		
1992-93	248.5	38.88		-97.38	9.51		
1993-94	382.8	43.80		-167.06	19.13	2	
1994-95	501.6	57.70		-212.70	8.63		
1995-96	613.0	64.77		-206.42	11.29	1	
1996-97	916.2	75.02		-232.55	16.11		
1997-98	1068.8	77.36		-232.10	13.33	1	
1998-99	1103.1	89.71	56*	-293.40	17.36		
1999-20	1295.5		36	-276.06	18.02	2	
2000-01	1542.3		46	-378.02	23.45	2	
2001-02	1637.2		48	-897.25	22.22	4	
2002-03	2058.3		72	-749.50	23.36	7	
2003-04	2473.4		44			11	

Note: * Cumulative number of patents granted during 1995 through 1999
Soutrce: Mani (2005); and Mani (2006)

On all the three indicators, the pharmaceutical industry has done much better even though both the industries received more or less equal amounts of state support. My argument is that the relative better performance of the pharmaceutical industry is to a large extent may be explained in terms of its sectoral system of innovation. This is because if research is done by Universities and other government research institutes and if production is done by business enterprises then building a bridge between the two is always a problem. As can be seen below the SSI of the pharmaceutical industry had at its centre stage actors like business enterprises, which had strong research and innovative capability. On the contrary the SSI of the telecom equipment industry had its centre stage a public laboratory devoid from production. Consequently the firms could implement the technologies that they developed (perhaps through reverse engineering) more effectively. This hypothesis is tested by examining the details of the SSI of the two industries.

III. The SSI of two Indian high tech industries

(a) The Pharmaceutical industry

The following figure (Figure 1) maps out the sectoral system of innovation of the phama industry. There are essentially five components to the sectoral system. In broad terms they are (i) Policy and strategic direction; (ii) The Intellectual Property Right Regime; (iii) Human resource development or the supply of scientists and engineers[2]; (iv) Technology generating sector; and (v) The manufacturing sector.

The three important components of the SSI are: (i) the public policy support; (ii) the manufacturing enterprises primarily in the private sector; and (iii) Government Research Institutes (GRIs). We deal with each of these components in some detail below:

(i) The public policy support

The market conduct or behaviour of the pharmaceutical industry in the country is subjected to the following policy framework. These could be classified as:

-Overall policy framework towards the development of pharmaceutical industry;
-Intellectual Property Right or patent regulations;
-Price regulations; and
-Product and quality regulations.

(a) Overall policy framework: The overall policy framework governing the industry up to this time has been the Indian Pharmaceutical Policy of 1994.This is because the new drugs policy formulated by the government in 2002 could not be implemented due to litigation involving it; hence the policy of 1994 still continues to be in force. The present Policy known as the Draft National Pharmaceuticals Policy, 2006[3] has been necessitated due to several developments that have taken place during the course of last few years as well as to address some of the major concerns as highlighted above. Price regulation of the essential medicines is an important component of this policy. However several other matters having a close bearing on the pharmaceuticals sector have also been included. Since the purpose of the present paper is to analyse the sectoral system of innovation of the Indian pharmaceutical industry, we will focus our attention only on those aspects of

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[2] The areas are medicinal chemistry; combinatorial chemistry; Bioinformatics and structure based molecular modelling , Genomics and proteomics, Clinical pharmacology, and Regulatory toxicology.

[3] Department of Chemicals and Petrochemicals, http://chemicals.nic.in/npp_circulation_latest.pdf (accessed on 11/08/2006)

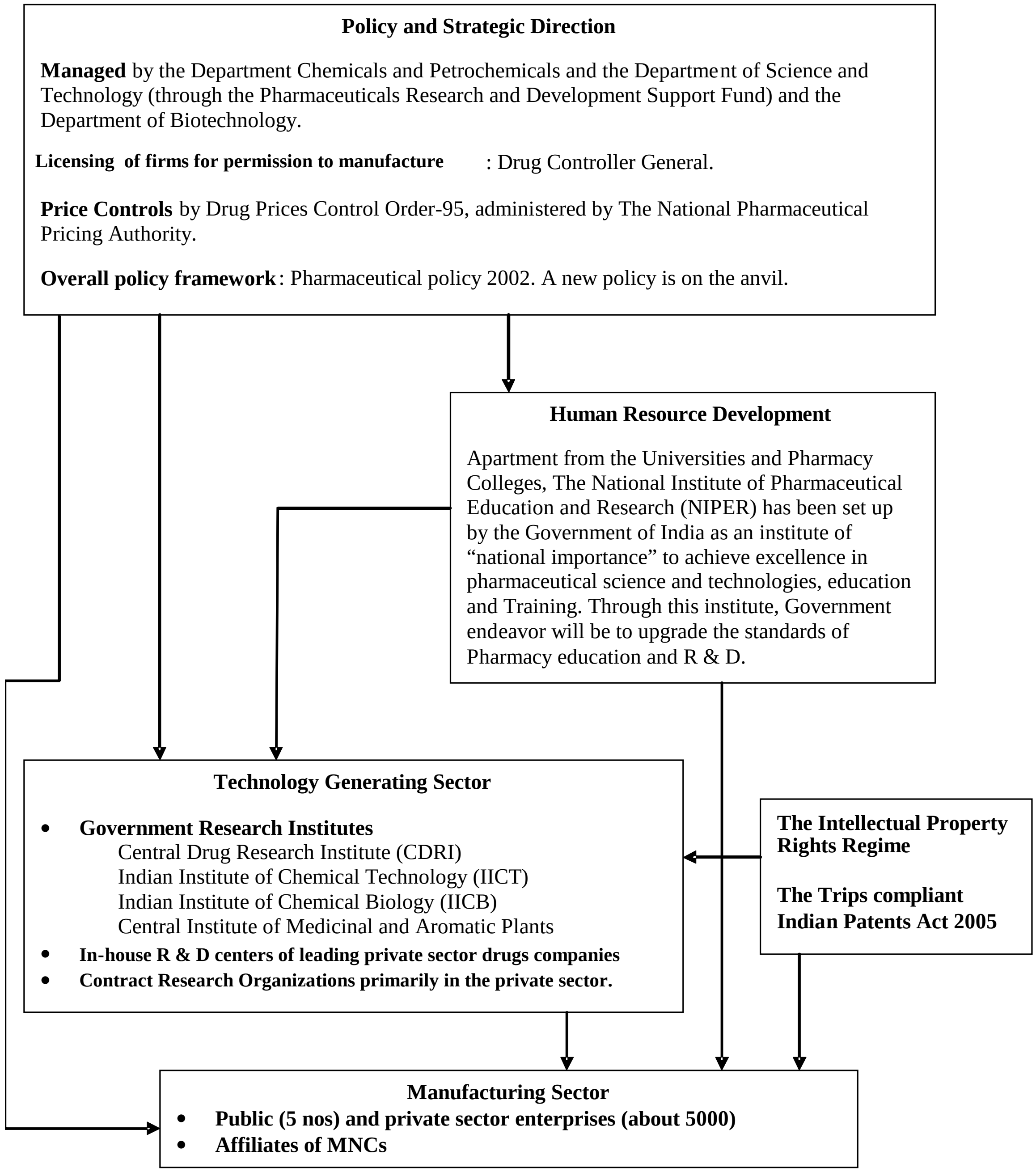


Figure 1: Sectoral System of Innovation of the Indian Pharmaceutical Industry (c2006)
Source: Own Compilation

the policy that explicitly deals with the promotion of innovation. The major policy initiatives in this area are summarized below:

i. Promotion of pharmaceutical R&D through the provision of fiscal incentives;
ii. Promotion of R&D intensive companies;

iii. Establishment of a pharmaceutical Research and Development Support fund (PRDSF); and
iv. Development of orphaned drugs

In the following I discuss the details of each of these four policy initiatives.

i. **Fiscal incentives for R&D:** a) The benefit of 150 per cent weighted exemption (under section 35{2AB} of the Income Tax Act of 1961)[4] is to be continued till 31st March, 2015; b) This deduction is to be extended to depreciation on investment made in land and building for dedicated research facilities, expenditure incurred for obtaining regulatory approvals and filling of patents abroad and expenditure incurred on clinical trials in India; c) Reference Standard (sample under test) would be exempted from import duty; d) Reference books to be imported for R&D would be exempted from import duty; and e) Presently there are 101 specified instruments (list 28) required for R&D purposes, which are exempt from import duty. With the ever-changing requirements new instruments are required to be imported. These instruments based on the certification of DSIR would also be exempt from import duty. The fiscal incentives are at present only available up to 31st March 2007. Since R&D activity has to be carried over long periods of time, fiscal incentives would be granted over a longer period of time extending up to 10 years i.e., up to 31st March 2015.

ii. R&D Intensive Companies (Gold Standard Companies): The Pharmaceutical Research and Development Committee headed by Dr R A Mashelkar in its report submitted to Government in November, 1999 recommended that R&D intensive companies fulfilling certain conditions should be given price benefits for the drugs under Drug Price Control Order (DPCO). It specified certain norms in this regard and termed these as the gold standards. Since six years have elapsed since this report was submitted it has been considered proper to revise these norms. The revised norms are as under: a) Invest at least 3 per cent of the annual sales turnover on R&D or Rs 500 million per annum, (average of last 3 years) whichever is higher on research facilities. b) Employment of at least 200 scientists in India (MScs or PhDs employed at least for one year). c) Own and operate manufacturing facilities in India which have been approved by at least two reputed foreign regulatory agencies (US, Europe, Japan, Canada, Australia, Israel, South Africa etc) d) Have filed at least 10 patent applications in India based on research done in India Companies fulfilling the above norms would be eligible for the benefit of 200% weighted deduction under 35(2AB) till 31st March, 2015 Additional incentives under price control measures may also be considered to such companies by Department of Chemicals and Petrochemicals.

[4] Income Tax Department, Government of India, http://www.taxmann.com/TaxmannDit/DisplayPage/dpage1.aspx?md=2&typ=se&yr=2006&ch=(accessed on 11/08/06)

iii. The Pharmaceutical Research and Development Support Fund: At present, the Pharmaceutical Research and Development Support Fund (PRDSF) has a corpus of Rs. 1500 million (where only interest income is available for spending) is utilized for funding R&D projects of research institutions and industry in the country. It is not adequate to meet the present day and the emerging requirements of this sector and there needs to be sufficiently augmented over the next five years. It has been decided to convert it into an annual grant of Rs. 1500 million, and thereafter it would be suitably increased further in a phased manner over a period of next five years. Priority would be given for R&D in case of diseases which are endemic to India like malaria, tuberculosis, hepatitis-B,leishmania (kala-azar),HIV/AIDS etc.

iv. Development of orphaned drugs: The Central Drug Research Institute (CDRI) has over time developed a number of drug technologies, which could not be commercially produced and marketed. Efforts will be made to identify such technologies with a view to enabling them to reach the market.

Further, the following two initiatives implied in the new draft policy has also further implications for promotion of innovation in the industry. They are: (i) abolition of industrial licensing for bulk drugs, intermediates and formulations; and (ii) automatic approval for foreign technology agreements through RBI.

(b) The Patent regime: It is now fairly well accepted that it is the provisions of the Indian Patents Act of 1970, and especially the fact this Act did not recognize product patents but only process patents, that allowed Indian pharmaceutical companies to reverse engineer and manufacture at significantly lower costs. But with the country becoming a member of the WTO in 1995, the patent regime has been made TRIPs compliant. This TRIPS compliance in very specific terms have led to the introduction of the following set of measures;

-The EMR (Exclusive Marketing Rights) provision was introduced with retrospective effect from January 1, 1995 (self-expunging provision which will be void on January 1, 2005)

-This transitional arrangement entailed India to provide for a mailbox mechanism for accepting product patent applications and for examining and granting EMRs till the time it accords recognition to product patents;

-Minimum patent term increased from 14 to 20 years

-Reversal of burden of proof from patent holder to alleged infringer

-The provisions relating to compulsory licensing have been modified to suit the public health requirements and also to comply with TRIPS.

-Introduction of product patents relating to Chemicals, Drugs, Medicines and Food Products

-Provision for pre-grant objection to patents has been diluted; and

-Grace period in case of publication of inventions;

The potential effect of these amendments on the innovative behaviour of the domestic industry is now hotly debated. One of the most important consequences is about the availability and prices of many essential drugs. Henceforth some of these drugs can only be manufactured under an explicit licence. According to Ramani, Pradhan and Ravi (2005), the Indian pharmaceutical firms have three choices open to them in a post TRIPS compliant regime. These are:

i. They can focus on products that are either off patent (essentially the generics market);

ii. They can collaborate with Western MNCs and biotech companies (two areas that are likely to witness an increase in collaborations are clinical trials and R&D outsourcing) and;

ii. They can focus on innovations that the MNCs will not be interested in; that is mainly 'tropical' or developing world diseases.

Although a bit too early to clearly measure whether the three possibilities are actually happening, there is enough evidence to show that (i) and (ii) are indeed happening. We will discuss this in some more detail in the subsequent sections. In the present we analyse, albeit briefly, the efforts undertaken by Indian pharmaceutical companies towards R&D in neglected but tropical diseases. This discussion is very largely based on Chaudhuri (2005).

The Indian private sector started investing in R&D for developing new drugs since the mid 1990s when TRIPS came into effect. According to current estimates there about 15 domestic pharmaceutical companies that are active in drug research and they have or are in the process of establishing new research centres with new drug discovery research (NDDR) as the major objective. The total R&D expenditure for the development of new drugs by Indian companies has increased from Rs 6.73 billion in 2002-03 to Rs 10.02 billion in 2003-04 and a number of new chemical entities (NCEs) have been developed which is at different stages of development. Since they do not have all the skills or the financial wherewithal required to engage in the entire process of drug development, they have adopted a strategy to develop new molecules and license out the molecules to the MNCs at early stages of clinical development. Consequent to this the Indian companies are effectively not targeting neglected diseases, but only those, which interest the MNCs. At this point, it is necessary to mention that the government has taken some initiatives for collaborative research to synergise the strengths of publicly funded R&D institutions and the Indian pharmaceutical industry. The only one area where some progress has been made is in the development of an anti-TB molecule (Lupin's development of the NCE LL 4858 is a case in point). However no special efforts have been made for the development of new drugs for most of the neglected diseases (such as malaria, HIV/AIDS, Chagas disease, Dengue fever, Leishmaniasis and Leprosy).

(c) Price regulations: Drug prices in India are among the lowest in the world (and imports are therefore negligible). This is because of several reasons. The first is that only product patents and not process patents (for pharmaceuticals) are so far recognized under Indian law. Therefore Indian manufacturers can make bulk drugs and formulations by "reverse engineering" of the overseas patented medicines, reducing R&D expenses and also avoiding royalty payments. Further, Indian labour costs are low compared to overseas levels. India also has a large pool of technical and managerial personnel and does not need management skills from overseas. Most of the plant and equipment required is made locally. Most importantly a measure of statutory price control for bulk drugs and formulations operates in India. Certain drugs (known as scheduled drugs, as they are listed in the First Schedule to the Drug Price Contol Oder (DPCO). The DPCO was introduced in 1970, but has since been modified three times, the latest one being in 1995. Over time the number of drugs under price control has been significantly reduced from 370 in 1979 to just about 25 in 2005. Non-scheduled drugs can be priced freely, subject to some restrictions. The National Pharmaceutical Pricing Authority (NPPA) administers the price control regime[5]. The Government can exempt certain products from price control if they are new drugs discovered in India or bulk drugs produced from the basic stage by a new process discovered in India or drugs manufactured by small-scale industries (capital investment below a certain level) and sold under their own brand names. The most important problem with respect to price monitoring is the absence of an appropriate price index. The government has been depending on IMS Health-AC Nielsen, (formerly ORG) for tracking data on retail sales both in volume and value terms. Therefore, having a pharmaceutical price index on the lines of the Consumer Price Index or Wholesale Price Index is being considered. Though details of the proposed index were not available, it is said that the government could create an index by having a basket of drugs whose prices would be benchmarked to a base year. It could then monitor any changes in their prices in relation to the index. However, the therapeutic segments that would form the basket would have to be decided. Also, whether the index would monitor prices of only generic drugs or include patented drugs as well would also have to be finalised.

(d) Product and quality regulations: The Drugs and Cosmetics Act of 1940 and its subordinate legislation Drugs and Cosmetics Rules (DCR), 1945 govern this aspect. The conduct of clinical trials- a growing area of importance is actually governed by this legislation. The government has decided to amend the DCR and has emphasised the incorporation of Good Clinical Practices (GCP) protocols and to make it legally binding to stress on the safety aspect of the patients and strict accordance to ethics. Towards this

[5] The functions of the NPPA, inter alia, are to: (i) implement and enforce the provisions of the Drugs (Prices Control) Order in accordance with the powers delegated to it; (ii) monitor the availability of drugs, identify shortages, if any, and to take remedial steps; and (iii) collect/ maintain data on production, exports and imports, market share of individual companies, profitability of companies etc, for bulk drugs and formulations.

direction the Department of Science and Technology (Government of India) established national Good Laboratory Practices (GLP) Compliance Monitoring Authority, with the approval of the Union Cabinet on April 24, 2002. GLP-compliance certification is voluntary in nature. The GLP in India are compliant with OECD norms and principles. Industries/test/ facilities/laboratories looking for approval from regulatory authorities before marketing them may apply to the National GLP Compliance Monitoring Authority for obtaining GLP Certification. So far there are only five Indian laboratories that have received this certification (Table 2).

Table 2: Profile of Indian laboratories with GLP certification

Sl. No.	Test facility	Areas of expertise	Year of recognition
1	International Institute of Biotechnology and Toxicology (IIBAT)	Physical-chemical testing Toxicity studies Mutagenicity studies Environmental toxicity studies on aquatic & terrestrial organisms Studies on behavior in water, soil and air; bioaccumulation Residue studies Studies on effects on mesocosms and natural ecosystems Analytical and clinical chemistry testing Studies on natural enemies and predators	2004
2	Dr. Reddy's Laboratories Limited, Discovery Research	Physical-chemical testing Toxicity Studies Mutagenicity Studies Analytical and Clinical Chemistry Testing	2004
3	Jai Research Foundation	Physical-chemical Testing Toxicity Studies Mutagenicity Studies Environmental Toxicity Studies on Aquatic and Terrestrial Organisms Studies on Behaviour in Water, Soil and Air; Bioaccumulation Residue Studies Studies on Effects on Mesocosms and Natural Ecosystems Analytical and Clinical Chemistry Testing	2004
4	Orchid Chemicals and	Physical-chemical Testing	2005

	Pharmaceuticals Limited	Safety Pharmacology and Pharmacokinetic Studies Toxicity Studies Mutagenicity Studies Analytical and Clinical Chemistry Testing	
5	Advinus Therapeutics Private Limited	Physical-chemical Testing Toxicity studies Residue studies Mutagenicity Studies Analytical and Clinical Chemistry Testing Environmental toxicity studies on aquatic & terrestrial organisms	2005

Source: National Good Laboratory Practice Monitoring Authority, http://indiaglp.gov.in/TestFacility.htm (25/01/2006).

(iii) The manufacturing enterprises

There has been confusion on the total number of pharmaceutical units in the country. This has been variously estimated to be about 19, 203 licensees. Citing the arguments and data provided in the Mashelkar Committee on drug regulatory issues, Chaudhuri (2005) argues that there are about 5877 pharmaceutical units in the country. This is because the number of pharmaceutical companies would be less than the number of licensees because manufacturing licenses are given to specific units and many companies have multiple manufacturing units. The structure of the drugs manufacturing sector in India is presented in Table 3.

Table 3: Structure of India's Pharmaceutical Industry

Type of enterprise	Number of enterprises
1. Bulk drugs	1333
2. Formulations	4354
3. Large Volume Parenterals	134
4. Vaccines	56
Total	5877

Source: Mashelkar Committee (2003), p. 49

According to Chaudhuri (2005), the bulks drug industry resembles that of a perfectly competitive industry with no one firm accounting for a significant share. Most of the units in this sector belong to the small-scale sector. Large private sector companies, on the contrary, dominate the formulations industry. See Table 4.

One of the most important features of the industry is the fact that it is largely dominated by domestic private sector enterprises. In fact there are only five MNCs in the top 20 and not a single public sector enterprise figure in the list. The two public sector enterprises, Hindustan Antibiotics established in 1954 and the Indian Drugs and Pharmaceuticals established in 1961, played an important role in creating a domestic private sector pharmaceutical industry (Chaudhuri, 2005, p. 34). This is best summed up by Smith (2000, p 33).

“Before HAL opened its doors, the domestic pharmaceutical industry was all but nonexistent. Furthermore, India’s universities had no provisions for the type of specialized training required by pharmaceutical companies. HAL’s founders took the initiative and laid a considerable part of the foundation that supports today’s local and MNC subsidiary drug companies. HAL created a demand for inputs in the form of skilled labor, specialized capital, and relevant services, and provided the critical mass for local pharmaceutical production, created jobs for tens of thousands, spurred innovation, and sparked industrial development in up and downstream businesses. These contributions eventually rendered India a favorable environment for pharmaceutical production, research, and distribution”.

Table 4: Top twenty companies in the retail pharmaceutical market in India, 2004

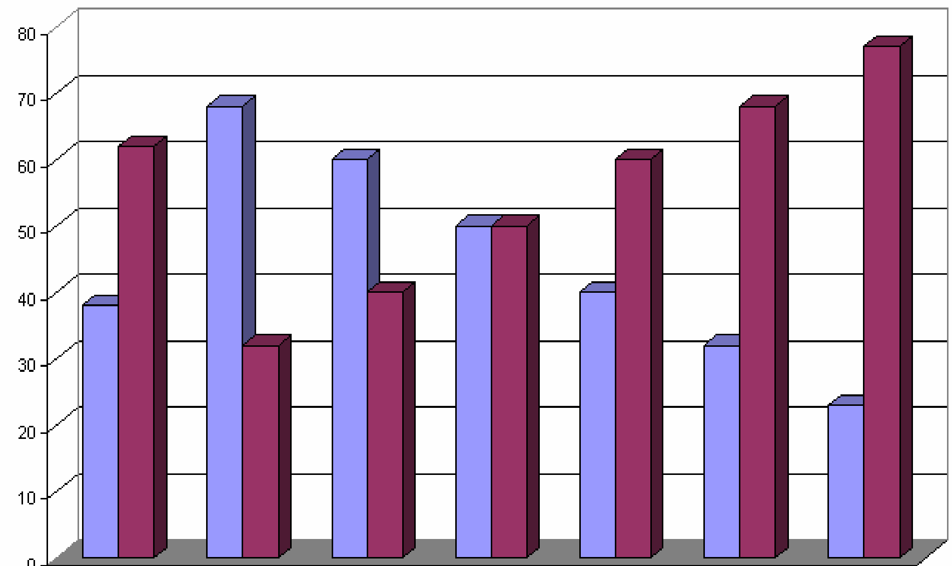
Rank	Sector	Company	No : of products	Annual sale in Rs Million	Market share (%) 2004
1	Indian	Cipla	707	11285	5.51
2	MNC	Glaxo Smith Kline	205	11143	5.44
3	Indian	Ranbaxy	437	9190	4.48
4	Indian	Nicholas Piramal	449	8720	4.25
5	Indian	Sun Pharma	350	6738	3.29
6	Indian	Dr Reddy's	183	4988	2.43
7	Indian	Zydus-Cadila	330	4959	2.42
8	Indian	Aristo Pharma	175	4760	2.32
9	MNC	Abott India	87	4735	2.31
10	Indian	Alkem Labs	310	4477	2.18
11	MNC	Aventis	44	4367	2.13
12	Indian	Lupin	274	4165	2.03
13	Indian	Micro Labs	461	3903	1.9
14	Indian	Wockhardt	238	3776	1.84
15	Indian	Torrent	150	3747	1.83
16	Indian	Novartis India	127	3725	1.82
17	Indian	Alembic	169	3432	1.67
18	Indian	Unichem Labs	189	3430	1.67
19	Indian	USV	86	3390	1.65
20	MNC	Pfizer	29	3274	1.6

Source: Chaudhuri (2005), p. 17.

However currently both these units are declared as “sick” or financially distressed companies by the Board for Industrial and Financial Reconstruction (BIFR) and are practically non-existent.

The amended patent law (1972) and the policy of positive discrimination towards indigenous companies vis-à-vis MNCs ensured that domestic companies currently (2004) account for nearly three quarters of the pharmaceutical market (Figure 2).

Although the data on market shares provided in Table 4 appears to give an indication that the market is fairly competitive, this is really not the case. The reason being the pharmaceutical industry is not a homogenous one but fragmented into different therapeutic segments such as tranquilizers, analgesics, antibiotics, vitamins etc. Each of



	1952	1970	1978	1980	1991	1998	2004
MNC (%)	38	68	60	50	40	32	23
Domestic Companies (%)	62	32	40	50	60	68	77

Figure 2: Market shares of Foreign and Indian Companies in the Indian pharmaceutical industry, 1952-2004
Source: Chaudhuri (2005), p. 18

these segments is a not substitute for each other. In fact the concentration ratios are much higher within a specific therapeutic group. For instance, Chaudhuri (2005) shows that, if one takes the various sub groups within antibiotics, the degree of concentration is much higher.

Another important structural aspect has been the increased number of mergers and acquisitions in the industry. In the period from January 2004-when Ranbaxy formalized its purchase of RPG (Aventis) for $80 million, making it the fifth-largest generics supplier in France-until October 2005, Indian firms made 18 international acquisitions (KPMG, 2006). Glenmark, Jubilant Organosys, Nicholas Piramal and Ranbaxy each acquired two overseas businesses during this time, but the biggest Indian buy was Matrix Labs' acquisition of Belgium's Docpharma for $263 million in June 2005. It is generally held that the pharmaceutical enterprises are currently the most aggressive overseas investors of all Indian industries. Several reasons[6] could be attributed to this mergers and acquisition spree. They are for the need to:

[6] See KPMG (2006), p.25

• Improve global competitiveness;
• Move up the value chain;
• Create and enter new markets;
• Increase their product offering;
• Acquire assets (including research and contract manufacturing firms, in order to further boost their outsourcing capabilities) and new products; and
• Consolidate their market shares

(iii) Government Research Institutes

According to Chaudhuri (2005), of the total pharmaceutical R&D expended in the country, nearly two thirds is contributed by the industry and the remaining by the GRIs primarily under the management of the Council of Scientific and Industrial Research (CSIR). Of the small number of new drugs that were developed by Indian inventors a lion's share were the products of research done at the Central Drug Research Institute (CDRI). CDRI is considered to be one of the few public sector organizations in the world, which have its own drug development infrastructure. Over the years it has developed and licensed to other private sector enterprises ten new drugs. Unfortunately most of the drugs according to Chaudhuri (2005) did not survive in the market owing to strong competition from MNCs.

Apart from the CDRI, which is directly connected with drug research, the CSIR system has 20 other laboratories that are engaged in some form of pharmaceutical research or other. Annexure 1 lists these labs with their areas of competence. Four of these led by the CDRI have been very active in drug research as indicated by the fact that they together account for a quarter of both Indian and foreign patents secured by the CSIR system (Table 5).

Table 5: Foreign and Indian patents granted to CSIR Labs engaged in drugs research, 2003-04

	India	**Foreign**
CDRI	7	5
CIMAP	7	29
IICB	4	5
IICT	24	39
Total for the above	42	78
Total for CSIR	275	212

Source: Computed from CSIR Website

(b) The Telecom Equipment industry

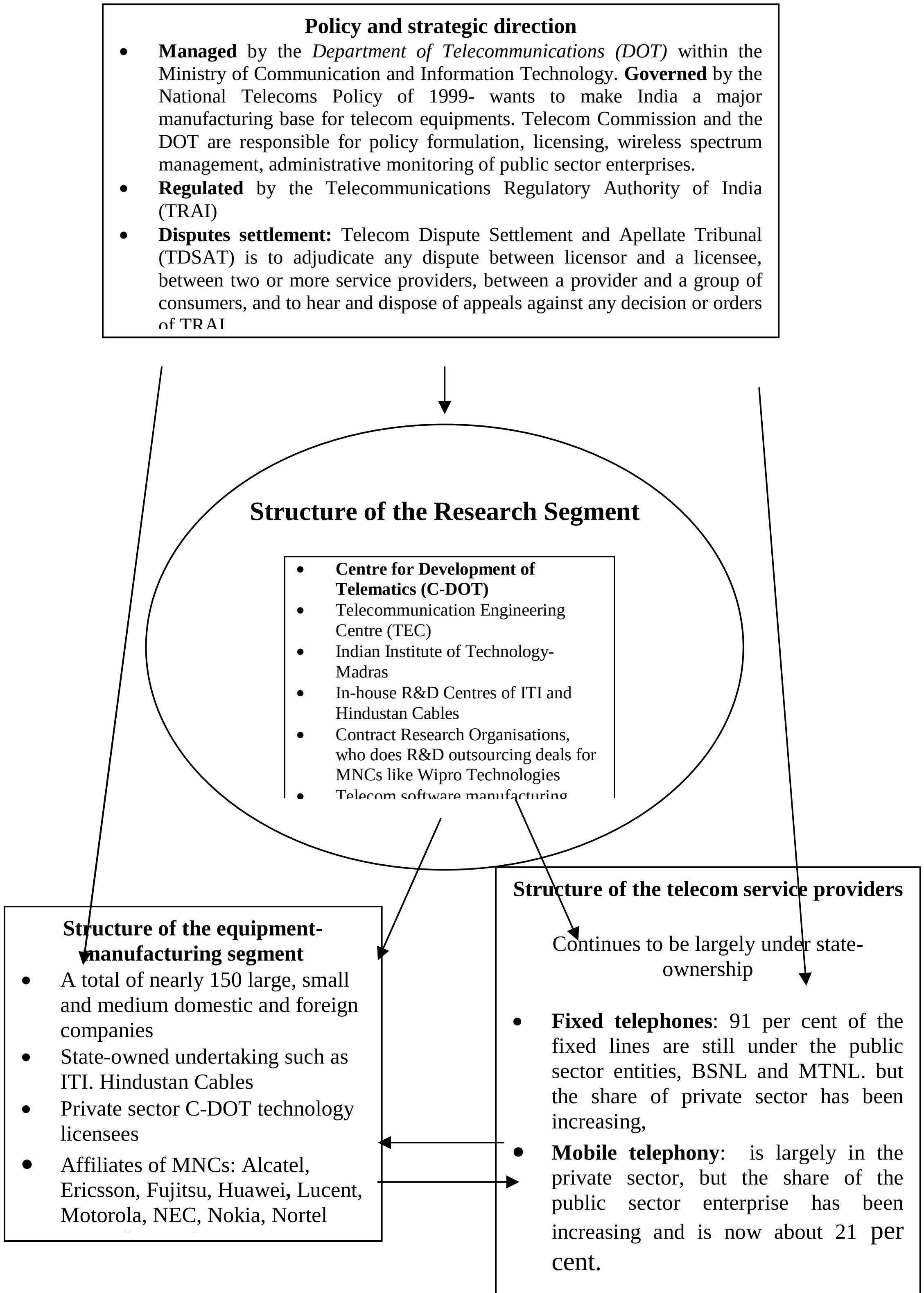


Figure 3: Sectoral system of innovation of the Indian telecommunications equipment industry (c2003)
Source: Own compilation

The SSI of the telecom equipment industry is mapped out in Figure 3. On the whole, India's sectoral system of innovation of the telecom equipment industry is very weak and fragmented. While the research segment, especially the dedicated public laboratory C-DOT, is very strong in terms of its capability to do successful R&D projects, there have been several attempts in the past to weaken its functioning (Mani 1995 and 2007, *forthcoming*). Compared to the Chinese one, the strategic direction from the state has been virtually absent[7]. Given the fact that the country was demonstrating a growing capability in computer software efforts should have been made to have a strong presence in telecoms software. This was, of course, accomplished subsequently in some measure by the private sector enterprises but with little or no state support;

The most distinguishing aspect of India's sectoral system for innovation is the central role that it assigned to the public laboratory, C-DOT. While the lab was successful in not just generating technologies that were quite suited to Indian conditions, it was able to effectively transfer the generated technology to a host of public and private sector enterprises. At the very same time it assiduously built up a growing number of component suppliers. In short, the laboratory is credited with establishing a modern telecommunications equipment industry in the country (Mani, 2007 *forthcoming*);

The drawback of this strategy was that the firms did not have their own in-house R&D centres and were dependent entirely on the technologies that they received from the public laboratory. The lab, as mentioned earlier, continued to focus on fixed telephony and that too on circuit switching technology, when packet switching was becoming the state-of-the-art. Further, it failed to take cognizance of the future in mobile communications (just like its counterpart in Brazil, the CPqD, but unlike its Korean counterpart, the ETRI[8]). The net result is that the licensing firms have become too complacent with respect to their own capability building. This is unlikely the Chinese strategy where the firms have built up considerable innovation capability on their own through their in-house R&D centres and have in addition acquired considerable production and marketing capabilities and has within a short span pf about 10 years emerged as internationally competitive;

During the period up to and including the 1990s, domestic Indian companies dominated India's telecom equipment industry. For instance, despite having a public technology procurement policy, which did not favour domestic equipment manufacturers, the share of indigenously designed and manufactured equipments accounted for over 50 per cent of market (Mani, 2007 *forthcoming).* However the country just did not have a strategy in place to make its leading state-owned equipment manufacturer, ITI, a national champion

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[7] The TIFAC did a major technology foresight exercise covering nearly 17 different areas including the telecommunications sector. Known as the 'Vision 2020' reports, these were published in 1996. Going through the list of seven major recommendations of the report on telecommunications one finds that the study did not anticipate at all the phenomenal growth of mobile telecommunications in the country.

[8] Mani (2007, *forthcoming*) has the details.

in sharp contrast to the strategy pursued by the Chinese. This will be evident when one makes a comparison of two leading telecommunications equipment manufacturers from China and India despite being an early starter, on every single indicator; the leading Chinese firm outperforms the leading Indian firm;

India has been a recipient of substantial FDI in telecommunications, although much of it is in the distribution of mobile communications services. Many MNCs including two of the leading Chinese telecom equipment manufacturers, Huawei and ZTE have established or are in the process of establishing manufacturing ventures in the country. The Department of Telecommunications (DoT) has set a target of attracting about $ 800 million in foreign direct investments in telecom manufacturing by March 2006. Cumulatively over the period 1991 through 2004, the country has attracted FDI in telecommunications to the tune of US $ 7.14 billion and this works out to about 18 per cent of the total approved FDI the country has received as a whole. As a result of these high foreign investments, the complexion of India's telecom equipment industry is fast undergoing a change with foreign affiliates and imports accounting or going to account for a significant share of the domestic market for telecom equipments.

In fact a recent study by the Department of Telecommunications (2004) found that currently (c2004) most of the domestic telecom equipment manufacturers and even the state-owned undertaking, ITI which till recently was the major equipment manufacturer, have merely become "trader" by importing the equipment and supplying it to the service providers[9]. The deregulation of India's telecom equipment industry had an extremely destablising effect on the operations of ITI (Subramanian, 2004) and its very existence was now in danger[10].

An important development in the country's sectoral system of innovation is the growth of R&D outsourcing deals between foreign MNCs and Indian contract research organizations in the area of telecom R&D. As this is a growing phenomenon, there are no precise estimates[11]. Even C-DOT, the nerve centre of the sector's innovation system, has

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[9] The study even states that 'in order to take advantage of lower customs duty, a separate procedure of "high –sea sale" is being followed. Even reservation quotas of PSUs are being used for trading goods manufactured abroad and without any commitment of transfer of technology". See Department of Telecommunications (2004), p. 4.

[10] Recently the Prime Minister Manmohan Singh has sanctioned Rs 10.32 billion for the revival ITI and IT has entered into a technical tie-up with Alcatel for manufacture of three million telephone lines. An announcement to this effect was made in the upper house of Indian parliament on March 24, 2005. See Economic Times, http://economictimes.indiatimes.com/articleshow/1061839.cms (accessed on 27/09/2006). Further recent press reports indicate that the company is going to take up the production of mobile communications equipments under foreign technology licensing.

[11] According to one of the leading consultancy organizations the R&D outsourcing market for IT in India is estimated to grow more than $8 billion by 2010 from $1.3 billion in 2003, at a CAGR of 30 per cent. There have been a number of high profile R&D outsourcing deals between Western MNCs and Indian enterprises, for instance the WIPRO-Ericsson deal, the Sasken-Nortel deal are two of three high profile deals in this area. .

recently entered into a contractual agreement with Alcatel to set up a global R&D centre for broadband wireless products[12].

I consider in some detail the three major components of the innovation system, namely (i) Public policy support; (ii) Manufacturing enterprises; and (iii) Government Research Institutes.

(i) Public policy support: The most important instrument of public policy support that was unique to this industry was public technology procurement. The government could practice this during th 1980s and even up to the early 1990s because the main consumer, the main telecom service provider, the Department of Telecommunications (DoT) and later on its corporatised version, the BSNL too was a state-owned undertaking. However in the latter half of the 1990s, the deregulation of the telecom seice provision market and the emergence of mobile communication has reduced state's ability to support domestic technology generation through public technology support.

However in during the best of times, the way the public technology support was actually practiced was not very beneficial to domestically developed technology by the public laboratory. This could be explained as follows.

The DoT purchases switching equipments only from local manufacturers and does not allow imports of finished switching products[13]. This really does not afford any protection to domestically assembled switches, but in fact quite the contrary. There are two types of evidences for this. First, imported equipments attract a customs duty of 15 per cent ad valorem(2002-03). At the same time the imported components for domestically assembled switches also attract customs duties and given the nearly fifty per cent import content of domestically assembled switches, the procurement policy does not afford any specific protection to domestically assembled or manufactured switches. Second, as noted earlier in Figure 4.8, the fall in price realisation of domestically manufactured equipments signal increased competitive pressures. Further in the past the rate of rejection of indigenously manufactured switching equipments by the DoT has been as high as 25 per cent in the early 1980s[14].

It has a decentalised telecom switches procurement policy. In order to simplify the procurement process, the department receives tenders and sets a fixed rate through a

[12] The project is to develop WiMAX (Worldwide Interoperability for Microwave Access) broadband technology. WiMax is a lot like WiFi, the short-range wireless technology that allows Web surfers to connect to the Internet at so-called hot spots. But unlike WiFi's 50-metre range, WiMax has a reach of one to 10 miles, offering a way to bring the Internet to entire communities without having to invest billions of dollars to install phone or cable networks.

[13] It must of course be added that the new private entrants are not governed by this stipulation and are free to import switching equipments.

[14] See Mani (1992), p. 97.

tendering process commonly known as "rate contract"[15] after which the Chief General Managers of the various telecom circles are authorized to purchase their requirements from approved vendors. The Telecommunications Engineering Centre (TEC) within the department sets the technical standards of all telecom products including switches. Thirty per cent of the total requirements of switching equipments are reserved for the public sector enterprise. However the price at which this thirty per cent is procured is at the lowest price quotation received for the remaining seventy per cent for which an open tender is invited. This reservation price is referred to as the L1 price. It is thus seen that the public sector producer of switching equipments have actually to bid for thirty per cent of the switching requirements without actually knowing the price at which the bid is going to be made. Thus it is clear that the public procurement process followed in the case of switching equipments does not afford any protection to the public sector producer, which in this case is ITI Ltd at Bangalore. The price-performance ratio is thus the main criteria for selection and not other non-technical considerations such as deferred credit facilities. At least for some more years, given the near monopoly position of the government carriers) public procurement policy will be an effective instrument for stimulating local R&D activities. However with the growth of private service providers this will be less effective, especially when the private sector providers, who are in the initial years of establishment, would also tale into account deferred credit facilities which only the MNC vendors can offer.

(ii) Government Research Institute

The government research institute, Centre for Development of Telematics (C-DOT), occupies the core of the SSI of the industry. C-DOT was established as a stand-alone public R&D organisation by the central government in 1984. It was charged with the responsibility of developing a family of digital switching systems that were suitable to the Indian usage pattern and conditions. Its scope has now been broadened to include transmission and access products as well. Over time, C-DOT has developed a wide range of switching and transmission products both for the rural and urban applications. It is claimed that while the C-DOT main exchange can also function as Mobile Switching Centre for GSM Cellular Service, the Small Rural Automatic exchanges developed for rural environment can work without air-conditioning. They come complete with SS7 Intelligent Network signaling systems16**.** In addition ISDN facilities are also available; what is unique is that these switches have been designed to operate without air-conditioning in harsh environments. About 45,000 exchanges totalling about 23 million telephone lines have been installed in India (As on December 31, 2001). This means that approximately 50 per cent of the equipped capacity in the country is based on C-DOT designed switches. Exports in bulk have been to about 22 countries such as Vietnam, Bangladesh, Nepal, Ethiopia, Nepal, Ghana, and Uganda. And this systematic vendor development shows that there have been considerable technology spillovers to

[15] The DoT receives and evaluates bids from domestic firms (including affiliates of MNCs) and awards rate contracts based on price and performance.

[16] These are the systems that are used to find out if a number is busy or available and involve a separate system that checks up the data bases of phone numbers ; also they provide toll-free services; in this way a the main telephone network does not get overloaded ; these systems are also used to interconnect Mobile and land based telephone numbers.

downstream industries as well. It has a R & D centre in Bangalore with complete test equipments such as , microprocessor development systems, CASE Tools, Object-Oriented methodologies, software metrics, along with V5.1, V 5.2 interface, SS7 signaling systems complete with the SSP, SCP and SMP systems. In fact C-DOT with a total manpower of 1300 employees has one of the fastest development cycle for digital switching systems any where in the world (Mani, 1995). C-DOT also claims to be having retrofitting capabilities- that is it has the capability to redesign some of the older switches that it has already developed and is currently being used in the network comply with more recent technological changes. This is achieved by making the necessary software changes. I have of course been not able to secure an independent confirmation of this capability.

I now turn my attention to measure quantitatively the innovation capability of C-DOT. Towards this direction, I consider two separate indicators of this capability. First is a summary measure of innovation capability based on production of C-DOT designed switches.. Second is a series of evidences to show the spillover effects of the technologies developed at C-DOT.

Indicator of innovation capability

There are two variants of this index. The first variant of this index is based on the relative market share of domestically designed (namely C-DOT designed and ITI-manufactured Main Automatic Local Exchanges (in terms of number of lines)) and foreign-designed but domestically manufactured (namely Alcatel-designed and ITI manufactured).[17] On technical grounds, both the technologies are considered to be equal. In very specific terms the index is defined as follows:

$$\text{Index of innovation capability} = \frac{\text{Production of C-DOT designed exchanges at ITI}}{\text{Production of Alcatel-designed OCB-283 exchanges at ITI}} * 100$$

[17] Currently the Indian telecoms carrier industry employs eight different types of switching technologies like C-DOT, E-10B and OCB-283 (Alcatel), 5ESS (Lucent technologies), EWSD (Siemens), FETEX-150L (Fujitsu) and NEAX 61E(NEC). Of all these 8 technologies, C-DOT is the single largest with a market share of 50 per cent.

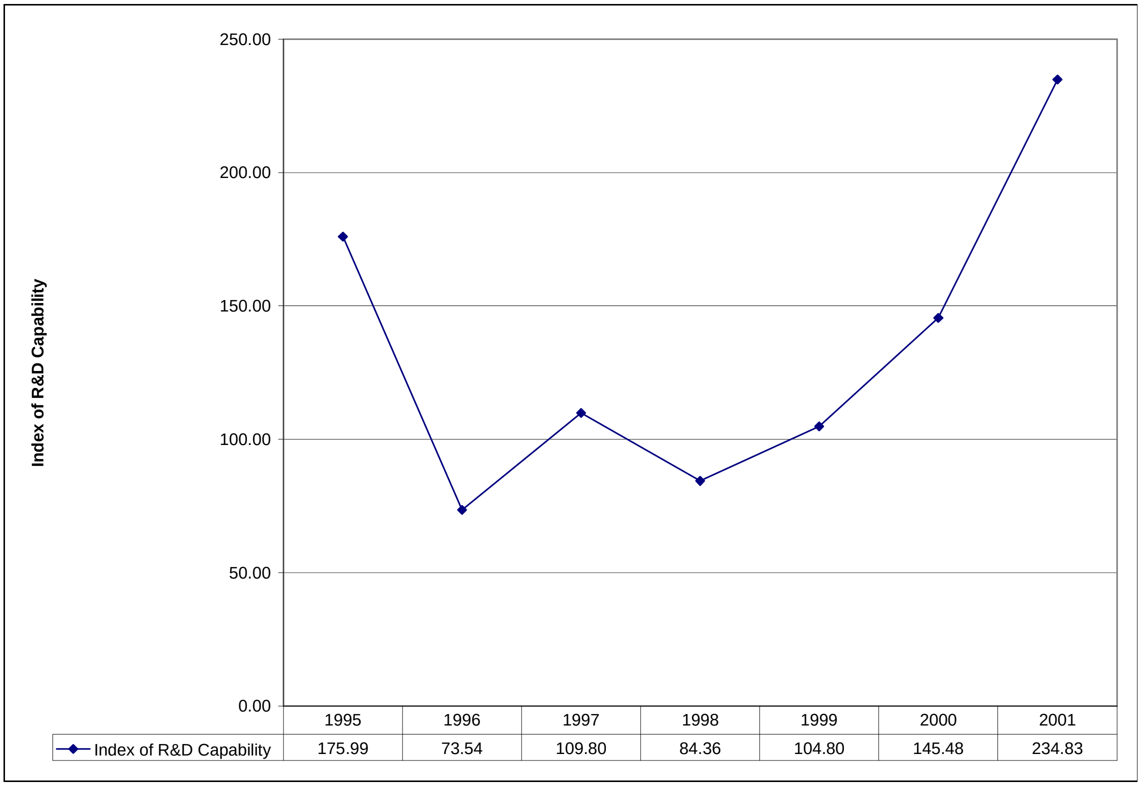

Figure 4: Index of innovation capability in Switching Equipments, 1995-2001
Source: ITI (various issues)

If the index is greater than 100 and increasing over time, one can say that the innovation capability of the domestic research sector is increasing over time. A major limitation of the index is that it is rather difficult to interpret short-term movements in the index. A second limitation is the fact that the index is defined in terms of production figures, and not in terms of number of working connections. But I argue that this will only affect the level of the index and not its direction of movement. This is because the share of C-DOT designed exchanges have been rising over time Based on the data during the period 1995 through 2001, the index has been computed and it is presented in Figure 4. Excepting for the initial year, the index shows that it has been showing a continuous rise over time implying a rising capability. This is quite significant as this has been happening at a time when the industry was going through a flux: the carrier industry was getting deregulated and MNCs were entering the equipment industry. So despite these factors, which can militate against the usage of domestically designed switches, one sees a systematic and continuous increase in its market share. As seen before this could be largely explained by the public procurement policy of the main consumer, the DoT.

The second variant is based on the number of lines of a switching technology actually commissioned within the network of the two main public telecoms service providers, namely within the DoT and the MTNL networks during a year. This variant is thus more of an index of market share of the various technologies and it is measured by the share of C-DOT designed switches in the total number of lines commissioned each year (Table 6).

This variant thus captures the effect of liberalization. In fact the index shows that despite public technology procurement, the share of C-DOT designed switches have continuously fallen all through the period. This of course proves that public technology procurement in the Indian does not afford any protection to domestically designed switches. This proposition could be further explained as follows.

Table 6: Share of C-DOT designed switches in the total number of lines commissioned in DOT and MTNL Network, 1994-1997

Type of switching technology	1993-94	1994-95	1995-96	1996-97
1. AXE-10	74000	169704	128300	113060
2. EWSD	107000	203500	297328	249544
3. 5ESS	10000	4000	132000	40648
4. FETEX-150	160000	93000	113200	93280
5. NEAX-61	Nil	10000	Nil	Nil
6. E-10B	766327	957330	1119994	523854
7. OCB-283	79500	311000	405720	490578
Total foreign technology (1+2+3+4+5+6+7)	1196827	1748534	2196542	1510964
8. Domestic technology *Of which:*	966583	1198516	112519	661905
• C-DOT: Large Exchange*	148500	186020	328625	206166
• C-DOT: Extra Large Exchange**	Nil	Nil	18800	11200
• C-DOT: Small *** Exchange	818083	1012496	774094	444539
Share of Domestic technology in the total number of lines commissioned (in per cent)	44.68	40.67	33.80	30.46

Notes: * Small and medium exchanges are those having up to 3000 lines; ** Large exchanges are those between 3000 and 10, 000; and *** Extra large are those having more than 10, 000 lines.

Source: Rajya Sabha, Unstarred Question No: 1171, http://164.100.24.219/rsq/quest.asp?qref=32199 (accessed on 26/09/2006)

(i) The Table tracks only the share of foreign and domestic technologies in the total annual flow of exchange lines commissioned. C-DOT's share in the total stock of exchange lines in the country is high at about 50 per cent with remaining 50 per cent shared by the other eight technologies;

(ii) C-DOT is specialising in small and medium exchanges, while the imported technologies are used essentially in large and extra large exchanges. It also a fact that C-DOT's capability is largely in small and medium exchanges, though it also has claims of capabilities in designing large and extra large switches;

(iii) It is also clear from an answer to an unstarred question in the upper house of the Indian parliament that the DoT procured almost five times the tendered quantity of switching equipments during the same period, supposedly for modernising the network with ISDN facility18. But the number of subscribers using ISDN in the whole country was just 309[19.] So it is clear that DoT appears to have purchased these 'overspecified ' equipments far in excess of its actual requirement and this 'excess purchase' appears to have eroded the market share of C-DOT;

(iv) Further the Comptroller and Auditor General of India (2000) found number of other irregularities with this tendering process. For instance, although the suppliers imported most of the components of theese switching equipments, DoT assumed import content as low as 23 per cent while working out reduction on rates on account of fall in customs duty in 1995-96 budget. This inaccurate assumption by DoT led to excess payment of Rs 405 million to the suppliers with corresponding loss to the government exchequer. DoT also had to make an avoidable expenditure of Rs 639 million in the procurement of these exchanges against 1997-99 tender due to failure of the Tender Evaluation Committee (TEC) to submit its report within the bid validity period. TEC took 190 days in finalisation of its report against the prescribed limit of 42 days; and

(v) Despite this fall in market share, C-DOT designed switches continue to occupy the single largest share.

(vi) In the light of the above comments, it would not be correct to interpret the fall in the overall market share of C-DOT designed switches to mean a fall in its innovation capability.

Spillover effects of C-DOT

Over the last two decades of its existence, C-DOT has made a number of important contributions both in money and in giving a fillip to domestic technology development in this area of high technology. These could be enumerated as follows:
(i) Since its inception in 1984, C-DOT has recouped approximately 25 per cent of the amount that its has received in the form of parliamentary grants through the sale of its generated technologies. This rate of self-generation has increased significantly to more than two thirds in the very recent past (Figure 8). This is a remarkable achievement as elsewhere in India, the network of laboratories coming under the purview of the Council of Scientific and Industrial Research (CSIR) has record of generating only about 10 per cent of their total income through self generation (Mani, 2002).

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[18] See Rajya Sabha Unstarred Question No: 4125 , http://164.100.24.219/rsq/quest.asp?qref=21560 (accessed on 27/09/06). According to the answer given by the Ministry of Communications, the DoT has actually ordered 0.91 million lines of digital switching equipments in response to a tender for just 0.2 million lines.

[19] See response to the same question no: 4125. From the same response it is also clear that the number of ISDN subscribers even in developed countries range from 0.5 million in the USA to just 40, 000 in Italy.

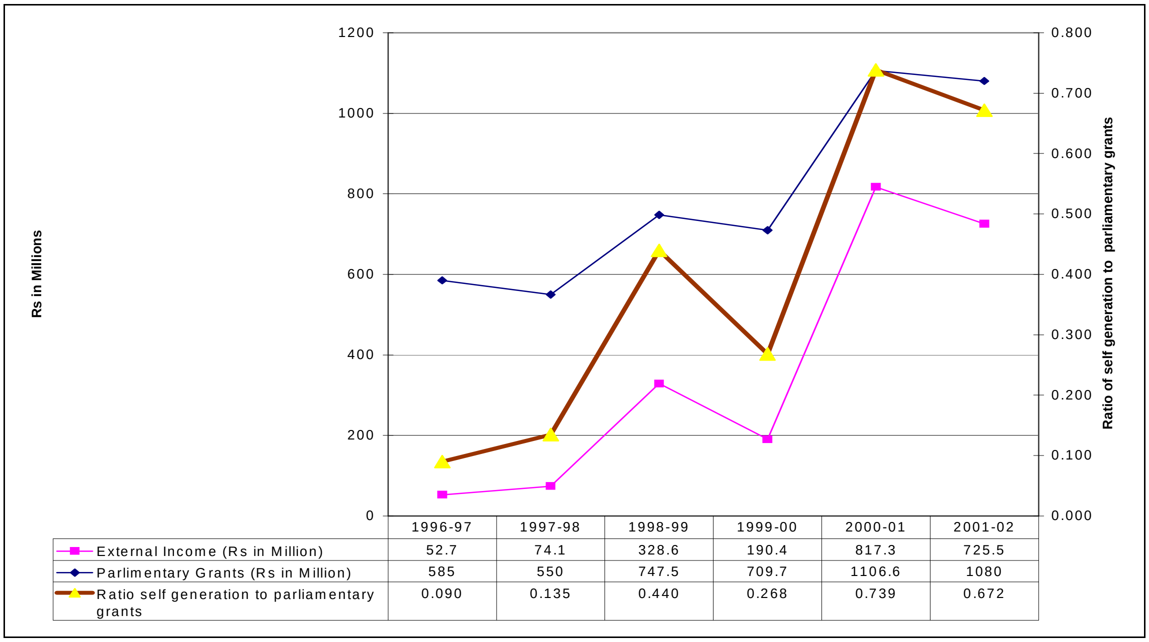

Figure 5: Ratio of self-generation through sale of technology to total parliamentary grants
Source: C-DOT (Various issues)

(ii) C-DOT 's technological innovations have contributed to a substantial reduction in the price of switching equipments sold in the country. In fact over the last one-decade prices have fallen by as much as 75 per cent. This fall in prices have enabled the country to increase the supply of direct exchange lines.

(iii) C-DOT has transferred eight different types of technologies to very nearly 74 manufacturers in the country (Table 7). These 74 companies have their own suppliers of components and spare parts numbering over 600 enterprises. C-DOT has thus effectively contributed to the creation of an indigenous telecommunications equipment industry in the country. More details of the industry are analysed in one of the subsequent sections.

Table 7: Technology transfer by C-DOT (Completed technologies)

Type of technology	**Number of manufacturers**
256 P RAX	14
SBM RAX	14
DSS MAX	13
IVRS	10
DMX-8	9
DMX-34	3
TDMA-PMP	6
OLTE-8	5
Total	74

Source: C-DOT (various issues)

(iii) C-DOT has pioneered the telecoms software industry in the country. Every year approximately 80 engineers (out of a total of about 1200) leave the centre. Since the development of modern digital switches is largely software based, this has given these engineers a strong background in the development of telecom software. The growth of the telecoms software sector is analysed separately.

While C-DOT has considerable capability in the design of fixed line switches, there is some doubt about its ability to design mobile switches. In fact my discussions at both the DoT, the TEC and with C-DOT revealed that C-DOT does not have, as of now, any real capability in the design of mobile switches. In fact no state agencies in India (including the Technology Information and Forecasting Assessment Council) has done a detailed technology foresight exercise for the telecoms sector so much to say that C-DOT , despite possessing the potential has been totally unprepared for this change over. This is going to be a serious shortcoming for C-DOT in the future, as the growth of mobile phones is likely to be faster than that of fixed lines. MNCs such as Lucent, Motorolla and Siemens have already established themselves as suppliers of state-of-the-art mobile switching centres to the cellular service providers. The problem is so severe that according the CEO of ITI Ltd (the largest telecoms equipment manufacturer in India), it had no orders for switching equipments for fixed lines from the largest telecom service provider in the country (namely BSNL) for the year 2003. Already there are reports of most of the licensees (switching equipment) of C-DOT having to close their manufacturing activities or scaling it down for lack of sufficient orders.

(iii) **The manufacturing enterprises**

There are about 150 enterprises of all sizes and ownership operating in the industry. They can be broadly divided into three: a large but financially distressed state-owned undertaking, ITI, a number of small and medium sized domestic private sector enterprises and a number of well known MNCs or their affiliates. The latter have entered the industry only during the period since 1985 when the manufacturing of telecom equipments were opened up to private sector and indeed even foreign participation. The equipment industry itself can broadly be classified into three: switching, transmission and terminal equipments. The switching equipment sector is largely dominated by the MNCs. The most distinguishing aspect of the manufacturing sector when compared to that of the pharmaceutical industry is that none of the domestic private sector manufacturers have any in-house research capability and the enterprises were completely dependent on external sources of technology. This I believe is an important structural weakness of the industry's SSI. This weakness is clearly reflected in the innovative performance of the industry (see Table

IV Conclusions

The pharmaceutical and telecom equipment industries are two high technology manufacturing industries that India has sought to promote. Once can easily discern a sectoral system of innovation in both the industries although there are important differences between the SSI of both the industries. Table 8 summarises these important cobtrasts between the two SSIs.

Table 8: Contrast between the SSI of the Indian Pharmaceutical and Telecom Equipment Industries

	Pharmaceutical industry	**Telecom equipment industry**
1 Degree of complexity in technology	Complex	Complex
2. The main actor	Domestic private sector manufacturing enterprises with strong in-house R&D capabilities	Government research institute with strong innovation capability
3. Main instrument of state support	The Intellectual Property Right Regime (Indian Patents Act of 1970)	Public Technology Procurement
4. Innovative performance	High	Low

Source: Own compilation

Employing three standard indicators of innovativeness, one sees that the pharmaceutical industry is more successful. Our explanation for this difference was largely in terms of the constitution of the respective SSI. Thus the present study is yet another instance[20] to show that a dichotomous relationship between research and production is not very desirable for promoting innovations in the industrial sector.

[20] China's innovation system was transformed all through the 1990s. In 1988 the Torch Programme was launched to encourage something like spin-off enterprises—called NTEs (New Technology Enterprises), from existing R&D institutes and universities. Local governments contributed to investment in infrastructure and supporting institutions for the New and High-Tech Industry Zones that became incubation bases for the NTE-startups. Scientists and engineers, often with support from their parent institutions, went into commercial application of their inventions and expertise by means of the creation of NTEs. And by the early 1990s, reform policy included another solution to change individual R&D institutes into production entities. This, as well, was an adaptation to an actual evolution already realized by many industrial R&D institutes.

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